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Survival of *Scutovertex minutus* (Koch) (Acari: Oribatida) under differing humidity conditions

Jaroslav Smrž

Department of Zoology, Charles University Praha, Viničná 7, Praha 2, 12844, Czech Republic

Summary. The moss-dwelling oribatid *Scutovertex minutus* was tested for three months in the laboratory under three different moisture conditions (flooded – moderately moist – dry) during which three types of food were offered (fungus *Bothrytis* sp. – moss – filter paper). Its population grew most successfully in water because these conditions produced the highest oviposition and hatching, whereas there was a high mortality under conditions of moderate moisture. Dry conditions induced temporary quiescence of adults broken by light or moisture, although the population survived and even slowly reproduced. Contaminating micromycetes (other than *Bothrytis* sp.) appeared to be the most important mortality factor. The tested groups differed from each other from the point of view of their behaviour (locomotion, aggregation) as well as in their microanatomical and physiological characteristics (alimentary tract, excretion) according to the experimental conditions. The opisthosomal glands of juveniles probably participated in the regulation of the water regime in the mite body. Generally, juveniles and adults survived under the extreme conditions, as a consequence of differing strategies.

Key words: Reproduction, mortality, behaviour, microanatomy, water stress

Introduction

Moisture has been considered to be one of the most important determining factor in the soil system (Wallwork 1976). Various authors have studied the reaction of animals to differing values of humidity (Madge 1961, 1964a, b; Beck 1983; Tamm 1984). The physiology of such processes has also been investigated (Vannier, 1978).

Many studies have revealed humidity preferences of soil animals and their consequences for community structure in various biotopes (Strenzke 1952; Wallwork 1976; Weigmann & Kratz 1981). Three categories have been determined: xero-, meso- and hygrophily (Wallwork 1976). Dwellers in biotopes with extreme fluctuations of humidity, e.g. moss covers on rocks, and trees have been assumed to be xerophilous (Madge 1961). On the other hand, the humidity in such covers fluctuates from extreme drying (5% of moisture: Smrž 1992a) to flooding conditions, the latter especially on horizontal solid substrates. This paper complements previous studies on extreme biotopes (Smrž 1992a, b) and is intended to compare the microanatomical, ecological, biological and ethological responses of their inhabitants.

Materials and Methods

Scutovertex minutus (Koch) was sampled from moss-cover on a roof in the city of Kladno (Central Bohemia). Mites extracted in Tullgren funnels were placed into a triplicate series of Petri dishes (20 specimens per dish) on double layered filter paper. Three groups were set up:

Flooded — constant water layer, mites were submerged throughout the experiment;
Moist — paper moistened (at 6 day intervals) to become moist only;
Dry — a 9 day cycle of moistening resulted in the paper being very dry for most of the experiment.
The temperature fluctuated from 18 to 22 °C.
In addition, three types of food were offered within each humidity group: filter paper only — moss (*Ceratodon purpureus* (Hedw.) Brid.) from the roof — fungus (*Bothrytis* sp.) isolated from the moss.
The populations were examined after six and twelve weeks respectively. Mites were fixed in modified Bouin-Dubosque-Brasil fluid (see Smrž 1989) (a sample only on first examination, and all specimens at the end of the experiment), embedded in paraplast, sectioned (thickness 3000—5000 nm) and stained in Masson's triple stain.
Eggs were isolated as soon as possible after oviposition, placed under the same three experimental conditions as the adults, and their hatching and subsequent larval survival observed.

Results

The situation after six weeks and three months respectively is shown in Table 1. The flooded conditions seemed to be the most suitable for population growth (especially on the paper only) in contrast with the moderately moist conditions with moss. The latter was heavily invaded by micromycetes different from the inoculated *Bothrytis* sp. (especially by *Penicillium* sp.). Such micromycetes were rare in the dry group and nearly absent in the flooded one.
As regards the mite distribution, the number of mites (adults as well as juveniles) were approximately equal on and under the paper in the flooded and moist groups. Under dry conditions, mites tended to aggregate on the underside of the paper. They were immobile until strong light induced their movement. Light seemed to be more effective than mechanical prompting in promoting a reaction.
In the flooded group, mites moved under water in every observation despite sinking. The rough cerotegument of adults, as well as the wrinkled cuticle of juveniles, seemed to be quite hydrophilous, except that their leg acetabula were covered by a "silver" layer under the

Table 1. Number of *S. minutus* during the experiment (from an original introduction of 60 mites per each nutrition group)

Group	After			
	6 weeks		12 weeks	
	Adults	Juveniles	Adults	Juveniles
Flooded				
Nutrition:				
fungus	37	35	11	19
paper	49	50	19	14
moss	25	29	6	21
Moist				
Nutrition:				
fungus	18	12	4	0
paper	19	11	14	0
moss	4	5	0	0
Dry				
Nutrition:				
fungus	40	23	16	6
paper	26	16	12	18
moss	5	9	2	0

water (especially in adults). Air confined probably to the cerotegument formed the silver strips from the margin of notogaster to the leg acetabula including the stigmae area. On being in water, all developmental stages sank immediately, without any "swimming phase". In the moist group, mites moved, but they were frequently caught and immobilized by the micromycete mycelium contaminating the Petri dishes, with lethal consequences for mites.

A very interesting phenomenon was observed during the extraction of mites from moss. They started their oviposition following emergence from the dried moss in the funnel into water in the extraction jars. This oviposition was noted at any time of year. The egg-hatching was most successful under water (100%) followed by 86% in the moist group and 64% in dry one. However, most of the larvae in the moist group were dead two days after hatching, whereas in flooded and dry ones they moved, though more slowly in the latter where the larvae were more wrinkled, dark and collapsed. Most of these collapsed larvae looked dead until immersed in water, where they became more swollen and revived after half an hour.

The internal anatomy of different groups exhibited some differences. The mesenteral walls of mites in the dry group proliferated exceedingly (Figs. 1, 2). The club-shaped projections of wall cells filled by guanine crystals were released into the mesenteral lumen within parts of the cells via apocrine secretion. The crystals mentioned were observed in faecal pellets in the rectum. Such guanine expulsion resulted in the coating of cuticle by its crystals. This type of excretion was observed in the moist group as well, but not in the flooded one. Mesenteron of the latter group possessed thick walls, especially in the antero-ventral part (Figs. 5, 6), but they were filled by more or less dark granulation, not by crystals.

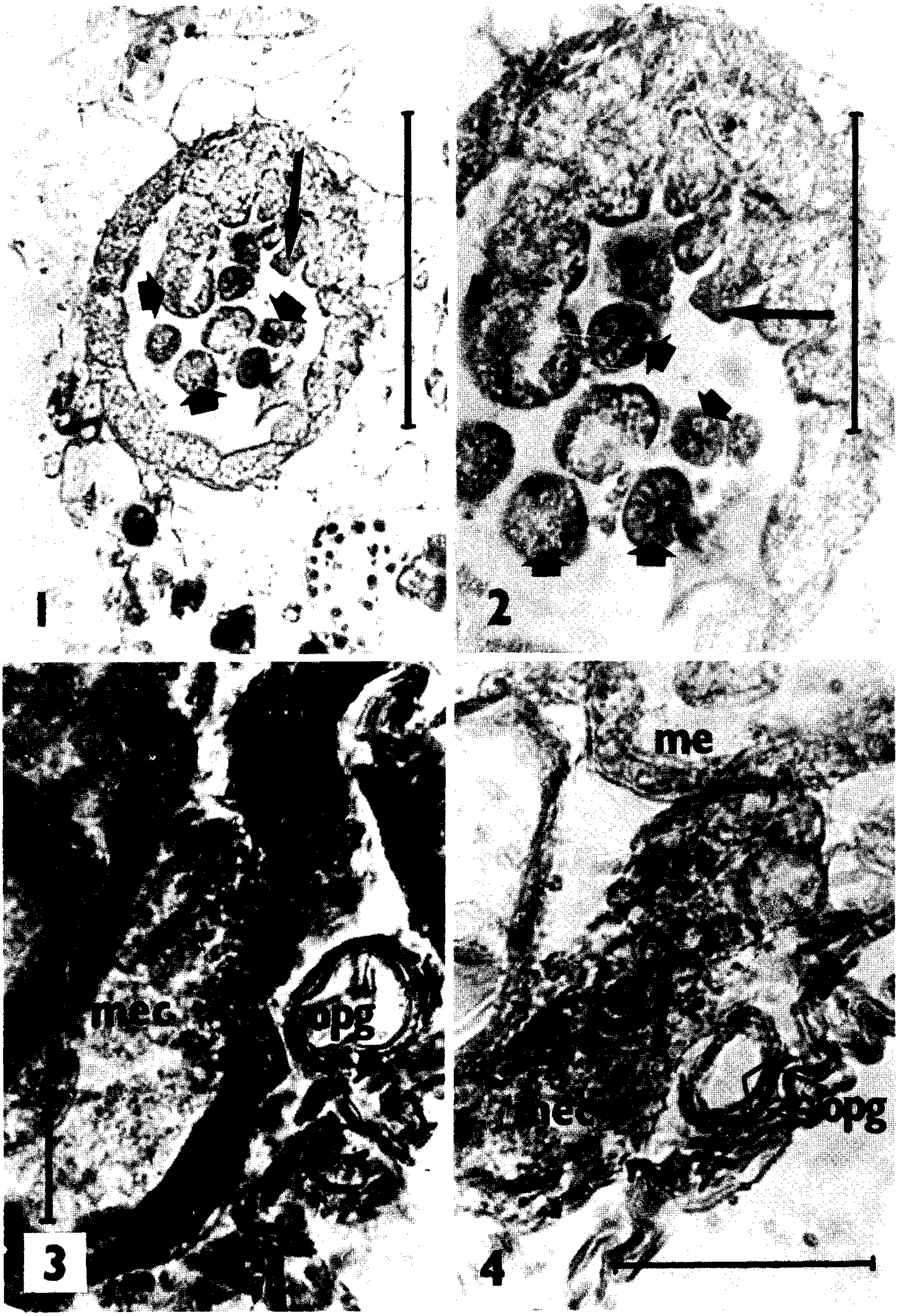
Food was consumed in all groups with no characteristic type of food bolus in the mesenteron, which contained a mixture of some amorphous matter and small portions of fungal spores and mycelium, all covered by a simple membrane (Figs. 5–8). The relative amount of spores and mycelium increased in the jars with *Bothrytis* sp. Generally, the consumption seemed to be continuous especially in juveniles. No remarkable reserves of nutrients were noted between internal organs in the parenchymal tissue of any group. The occasional consumption of fungi invading into the most group jars was probable as well, though the gut was not filled by food in all specimens studied in this group. The colon of these mites, however, exhibited remarkable changes: its walls were swollen, compact, in comparison to the other mites.

Juveniles in the flooded group were more transparent than in the others; their voluminous opisthosomal glands were red-coloured as were the supracoxal glands.

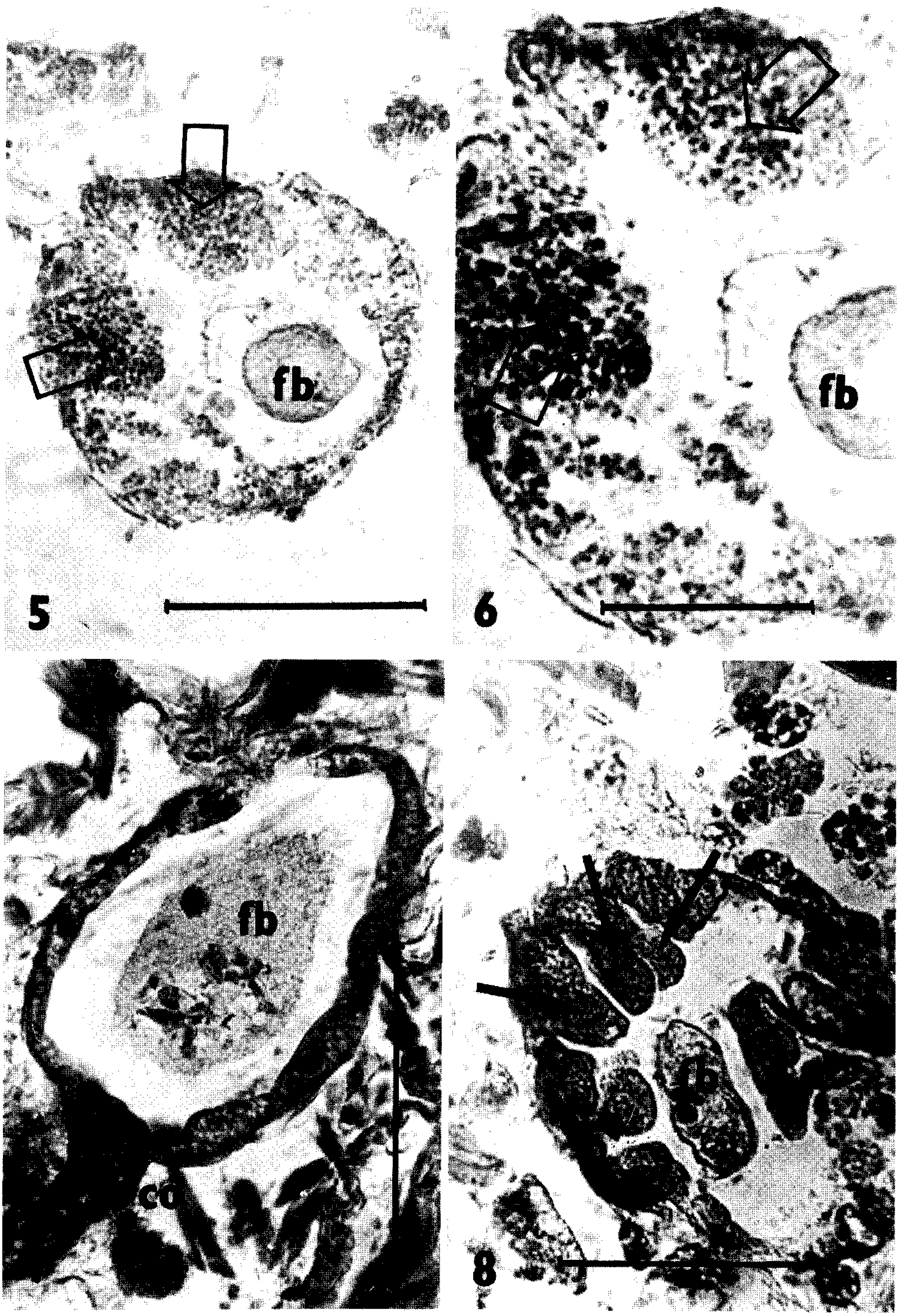
Spermiogenesis and oogenesis proceeded in all groups in a similar manner; spermatids and spermatozoa being present in the vesiculae seminales of males of all specimens studied as well as at least one egg in females, for the whole time of the experiment.

Discussion

Scutovertex minutus is one of the well-adapted dwellers in extreme biotopes with fluctuating abiotic factors, especially humidity. It surmounts them due to its anatomical and physiological adaptations (Smrž 1992a). Extreme dry conditions do not represent the most hazardous factor for these mites in experiments. The resistance of arboricolous and saxicolous mites against drying was considered by Madge (1964b). The resistance of *S. minutus* to both humidity extremes was expressed by its successful reproduction in both (the flooded and dry groups respectively in our experiment). Moreover, locomotory and reproductive activity, as well as ontogenetical development under water, differed from other arthropods (including dwellers in inundation zones), which hatch after flooding or else avoid it (Beck 1983; Tamm 1984). The paradoxical mortality of mites in the theoretically suitable, moderate humidity (the moist group) can be correlated with the growth of fungi that invaded the experimental jars. They are dangerous for mites due to their mechanical (obstacle to locomotion) as well as probably toxic or antibiotic effects via occasional actual consumption



Figs. 1–4. Horizontal sections, dry group: 1 – Mesenteron with proliferating parts of cells filled by guanine crystals (longer arrows), free cell parts (short arrows); 2 – the same in detail; 3 – opisthosomal gland adjoining mesenteral caecum; 4 – the same, more ventral section. Abbreviations used: me – mesenteron, mec – mesenteral caecum, opgl – opisthosomal gland. Scales: 0.1 mm (1, 3, 4), 0.05 mm(2).



Figs. 5–8. Horizontal sections through mesenteron, flooded group: 5 – enzyme granules in anterior part (empty arrows); 6 – the same in detail; 7 – walls without remarkable thickening or granules concentration; 8 – intensive proliferation – apocrine secretion of enzymes (longer arrows), free cell part (short arrows). Abbreviation used: co – colon, fb – food bolus. Scales: 0.1 mm(5), 0.05 mm (6, 7, 8).

of them, or of the substrate (paper) with their exudates, or via simple contact. Such influences may be indicated, e.g. by the histological changes of colon of mites in the moist group. They were not preferred being consumed rather occasionally by mites, unlike *Bothrytis* sp. isolated from moss and inoculated into the experiment chamber. This fungus seems to be well-adapted for these extreme moisture conditions and their fluctuation. Invasion of other micromycetes has probably been inhibited by both moisture extreme values.

No clear food selection was noted in the experiments. The mixture in food boluses appeared to confirm the panphytophagy of *S. minutus* as published earlier (Luxton 1972; Smrž 1992b). On the other hand, the absence of any reserves within the parenchymal tissue between the internal organs can indicate a lower grazing intensity, or a lower palatability of food available, resulting in the lower assimilation of nutrients from food. A high assimilation was reported in our experiments with mycophagous *Damaeus onustus* reared on *Bothrytis* sp. (Smrž & Trelová 1993) with consequent deposition of reserves. Similar results were published by Vannier (1978) for Collembola.

The silver coating at the leg acetabula indicates a similar structure to the plastron used for respiration by the submerged animals, as also described for the hygrophilous oribatid *Hydrozetes* sp. by Krantz & Baker (1982). Hence, *S. minutus* needs no "swimming phase" on the water surface usual in other oribatids lacking the extended plastron-like cover described above. For example, most of specimens (adults and juveniles) of *Trichoribates trimaculatus* from the same habitat as *S. minutus* swam on the water until they died (unpubl.). Beck (1983) considered that most soil animals from the inundation zone avoided the flooding (Collembola) or rested as eggs (slowly moving mites). The latter were noted by this author to hatch after drying of the habitat. Similar conclusions were drawn by Tamm (1984) from laboratory experiments.

Some role of opisthosomal glands in the water regime was indicated in juveniles of flooded and dry groups respectively as a consequence of their differing appearances. Their role in water relations can be supported by their close contact with mesenteral caeca and mainly by the striking red colour, identical with that of the supracoxal glands. The function of the latter glands has been explained by Woodring & Cook (1962) and Knülle (1984). An excretory function for opisthosomal glands was suggested by Jalil (1972) and Smrž (1992a, b).

Both filter paper and *Bothrytis* sp. seemed to be more palatable than moss, probably also due to the contamination of the latter group by some fungi introduced along with the moss. Nevertheless, the artificial environments, as well as the not quite natural food, probably resulted in the general decline of the population by the end of the experiment.

The main reproduction time of *S. minutus* was noted as July (Smrž 1992b), but the occurrence of the matured eggs, spermatozoa and juveniles of all stages during the whole year indicated their operative oviposition triggered by suitable conditions of a non-periodical nature (humidity, temperature). Mass oviposition as a response to water immersion after extraction confirms this. Under these experimental conditions no oocyte or egg resorption as described by Crawford & Warburg (1982) was noted. The egg hatching of *S. minutus* under water indicates a survival strategy rather different from that of *T. trimaculatus* (see above) or that of animals mentioned by Beck (1983) or Tamm (1984) as avoiding or resting in these situations. Therefore, the populations of *S. minutus* are able to flourish in biotopes with extreme humidity conditions (moss covers of roofs: Smrž 1992a, b), or in very wet ones (very wet meadows, flooding areas of salt marshes: Weigmann 1973). Furthermore, the survival capability of adults and juveniles appears to be comparable although their strategies are different from each other: juveniles use their voluminous opisthosomal glands, guanine deposition and respiration through the weak cuticle, whereas more heavily sclerotized adults respire under water via their plastron structures. The artificial nature of these experiments must be emphasized, and therefore the interpretation of results and their extrapolation should be viewed with caution.

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